Using AIRS Profile Information to Better Assimilate AIRS Radiances in GSI

Bradley Zavodsky (NASA/MSFC)

Jayanthi Srikishen (USRA)

Gary Jedlovec (NASA/MSFC)

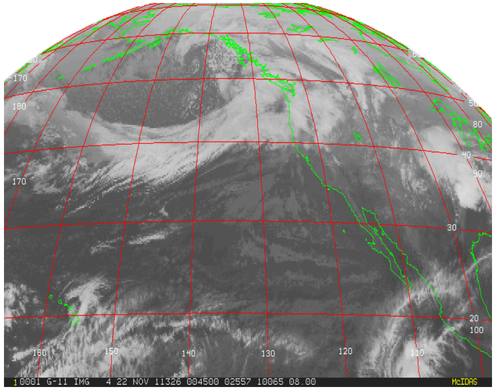
The 11th JCSDA Workshop on Satellite Data Assimilation

7 June 2013

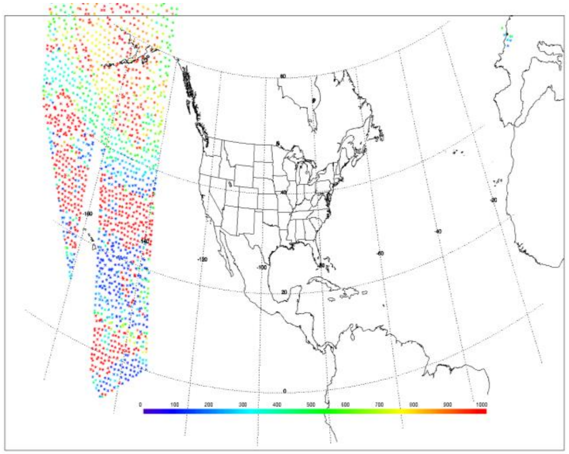
Motivation

- **AIRS radiances currently assimilated operationally in GFS and NAM**
  - Cloud-free radiances from 281-channel subset
  - Cloud checks performed within GSI to determine which channels peak above cloud top
  - Inaccuracies may lead to less radiances assimilated or introduction of biases in cloud-contaminated radiances, so need to find proper balance
- **Use information from AIRS L2 retrieved profiles to better understand the <u>optimal distribution of AIRS radiances assimilated within GSI</u> to engage the operational DA community regarding strategies for assimilating hyperspectral radiances**

GOES IR imagery showing cloud locations



GSI diagnoses CTP to determine radiances to assimilate

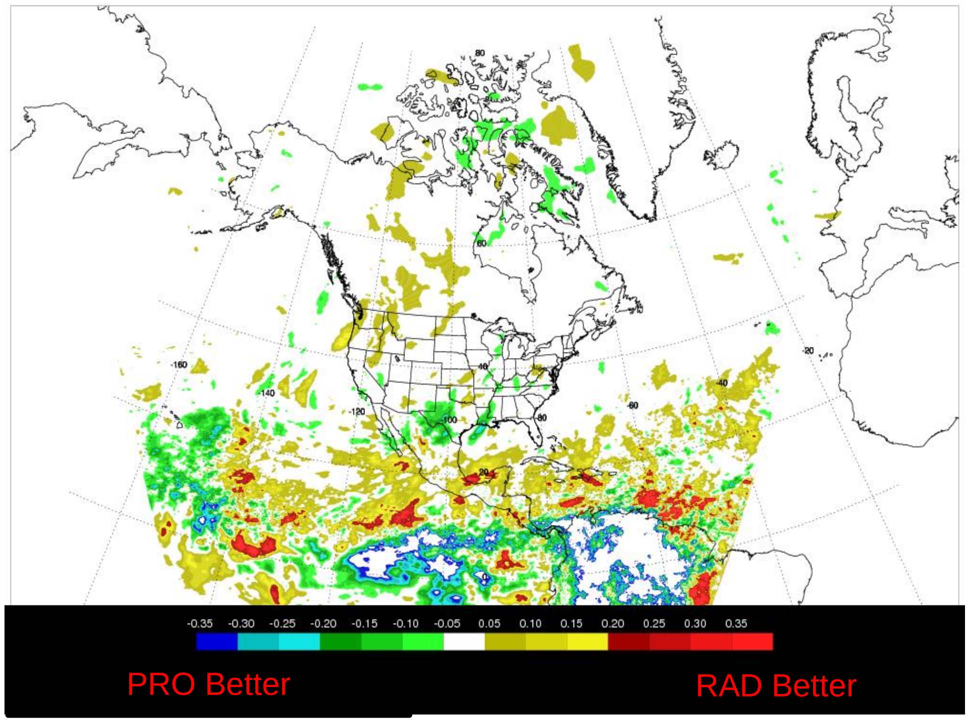


- **Use retrieved CTP from L2 to determine regions where additional channels might be assimilated**
- **Compare to MODIS as to determine cloud location and vertical extent**

Previous Results with P_{best}

- **Demonstrated that there was additional information that could be included through use of AIRS L2**
- **Used P_{best} to define highest quality AIRS L2 data**
  - **This does not necessarily transition to an operational implementation because use of cloud clearing in the radiances means that more contaminated radiances may sneak in if P_{best} is used**
  - **Operational implementations of cloudy radiances have focused on CTP**
- **P_{best} has been shown to roughly correlate to CTP, so instead of using P_{best} let's look at CTP from AIRS to develop methodology to modify GSI**

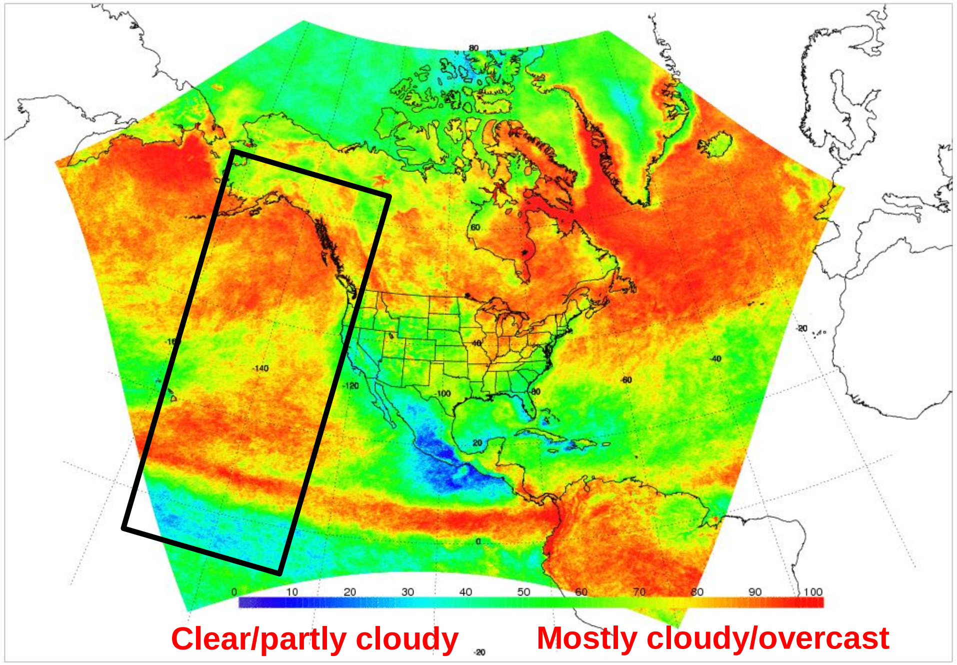
*Mean (21 Nov-19 Dec 2011) 500 hPa T AC difference at F48 for 00Z initialization**



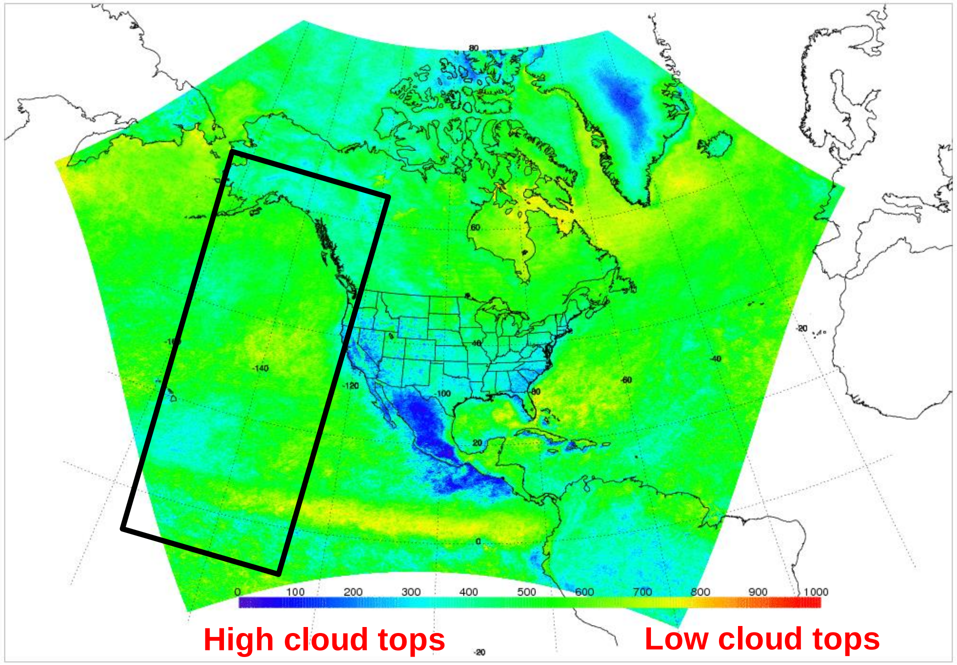
**note that large white areas in center of green and blue areas are artifacts of the plotting routine*

Bulk Cloud Information

Mean MODIS cloud fraction: 20 Nov - 20 Dec 2011



Mean MODIS CTP: 20 Nov - 20 Dec 2011

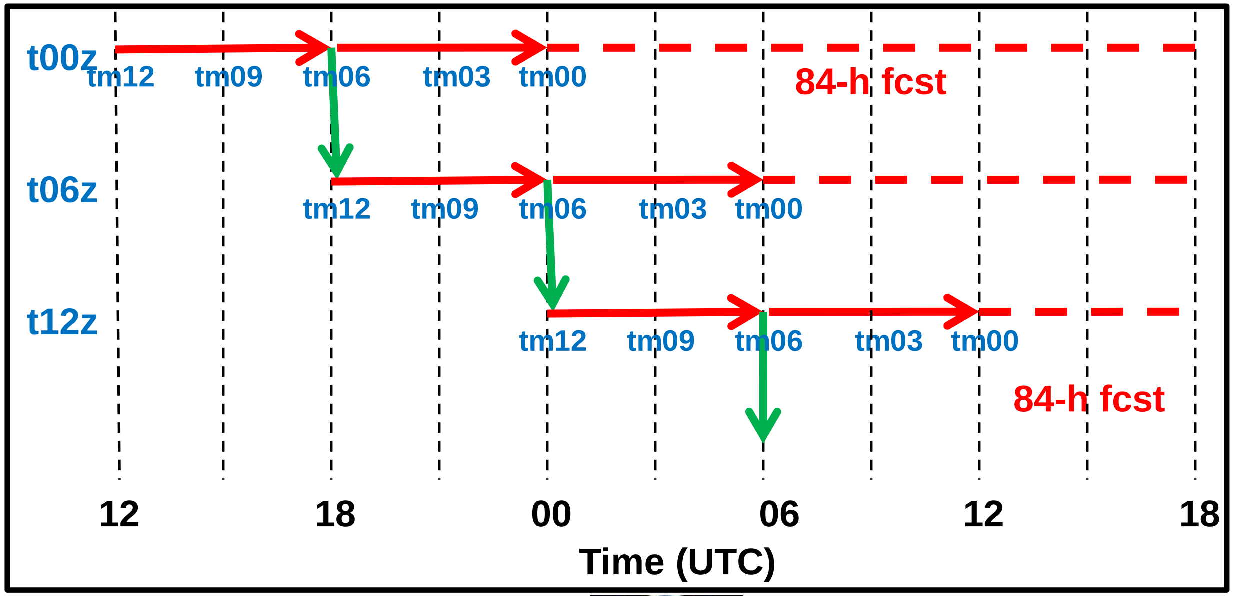


- **Mean cloud information from Aqua MODIS interpolated to WRF-NMM grid**
- **Initially focus on regions of low- and mid-level, opaque clouds should be areas where CTP should be defined in both**
- **Main focus of results will be on persistent low- and mid-level, opaque clouds in Pacific and will focus on 5 days with interesting cloud features for “00Z analysis” region**

Experimental Setup

- **Developmental Testbed Center (DTC) GSIv3.0 and WRF-NMMv3.3 code configured in forecast cycling methodology that mimics the operational NAM**
- **Real-time BUFR files archived during assimilation period (4 Nov.–20 Dec. 2011)**
  - Satellite: AIRS, AMSU, HIRS, MHS, GOES Sounder, GPSRO, radar winds
  - Conventional: All observations used in EMC's Table 4
- **Two "parallel" 4-week experiments with 2-week spin-up:**
  - RAD:
    - assimilate AIRS radiance data using operational procedures
  - PROF:
    - match nearest AIRS L2 CTP to location of radiances in "airsev" BUFR file
    - modified GSI source code to replace CTP derived from AIRS L1B radiances with CTP from L2 profiles

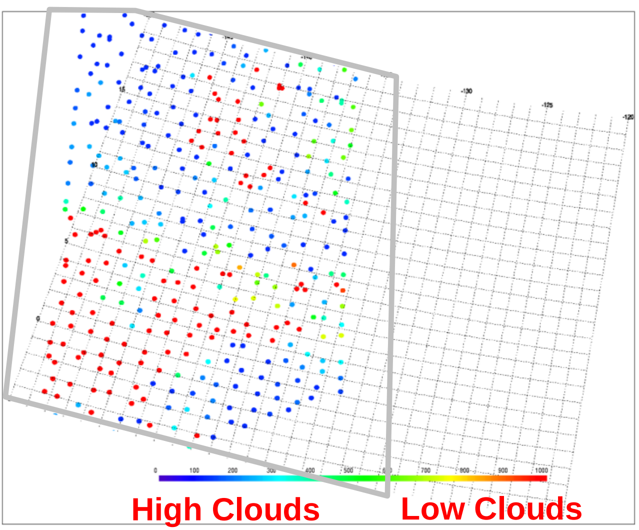
Schematic for GSI scripts (DiMego, personal communication, 2011)



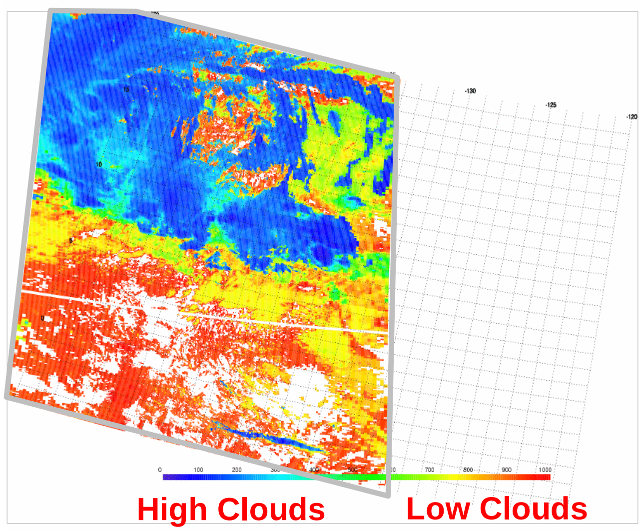
"Swapping" AIRS L2 CTP

- **Generate a file from AIRS L2 matching the radiance locations in the BUFR files to the closest CTP in L2 profiles (not same resolution so there are overlaps)**
- **Within GSI QC procedures, swap the CTP and analysis sigma level with information from the L2 CTP that determine which radiances to assimilate**
- **Overall, GSI QC does a good job of determining cloud top pressure (CTP) patterns and AIRS L2 appears to miss small-scale breaks in the clouds**

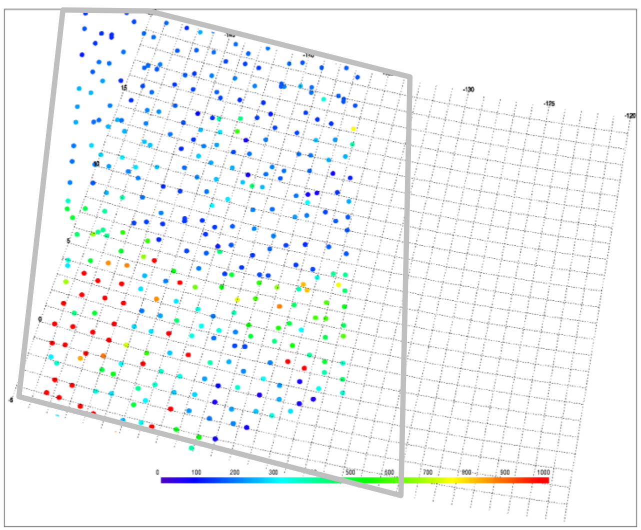
GSI CTP for 0000 UTC analysis on 22 November 2011



MODIS CTP valid 2240 UTC on 22 November 2011



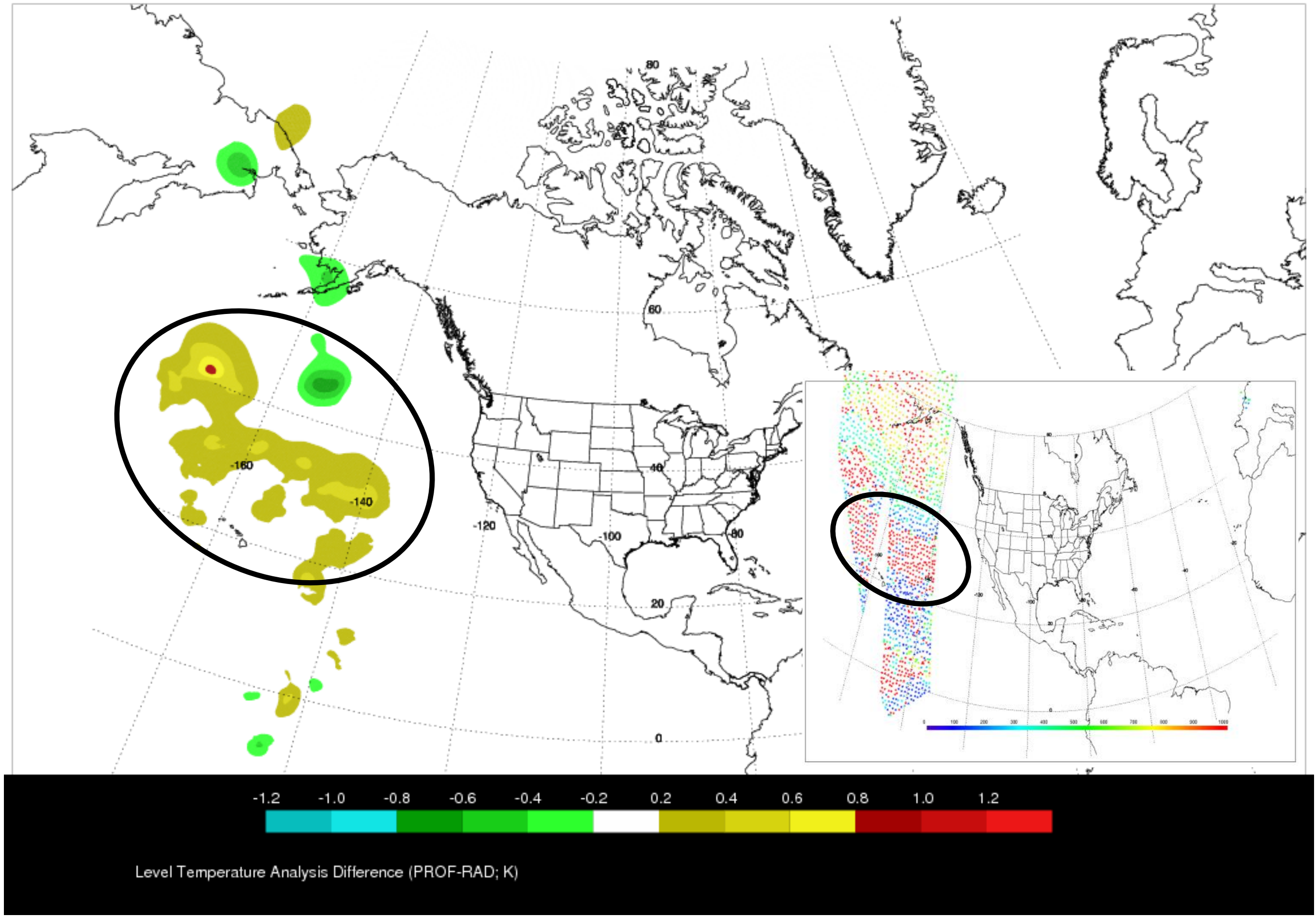
AIRS L2 CTP valid 2240 UTC on 22 November 2011



Analysis Differences with L2 CTP

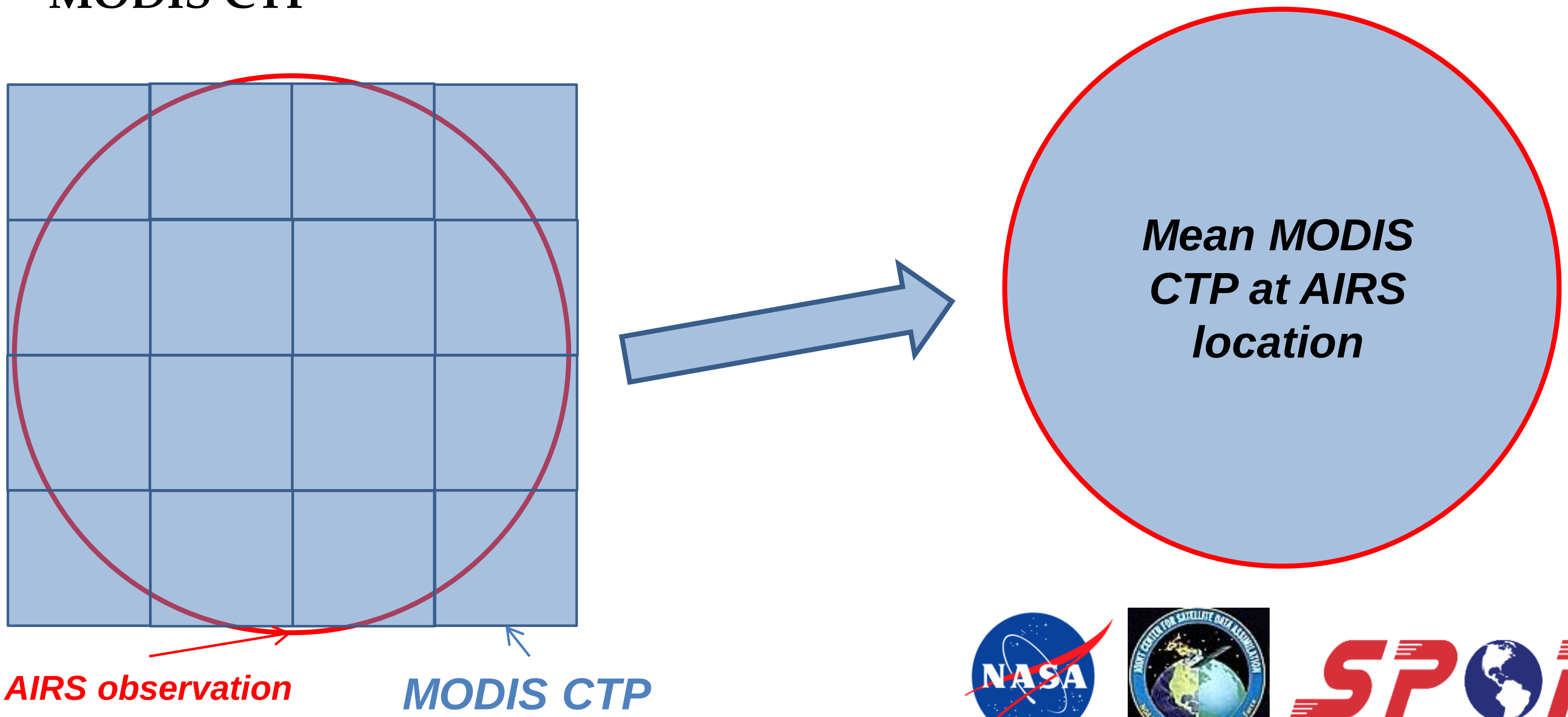
- Sanity check to ensure that there are non-trivial differences when L2 CTP are used
- Differences indicate that mechanics of the technique are being used by GSI and differences are occurring within the bounds of the assimilated data
- Largest differences occur in regions of low clouds and clear skies

Temperature (K) analysis differences (PROF-RAD) at σ=39 (≈500 hPa) for 00Z analysis on 22 November 2011



Matching up MODIS CTP

- Compare CTP from GSI and AIRS to MODIS 5-km to determine whether there are improvements with assumption that MODIS CTP is "truth"
- Use output from GSI diagnostics to determine CTP used for assimilation in each experiment
- Find the mean of all MODIS CTP within AIRS radiance footprint
- Determine the difference between the PROF or RAD diagnosed CTP and the MODIS CTP



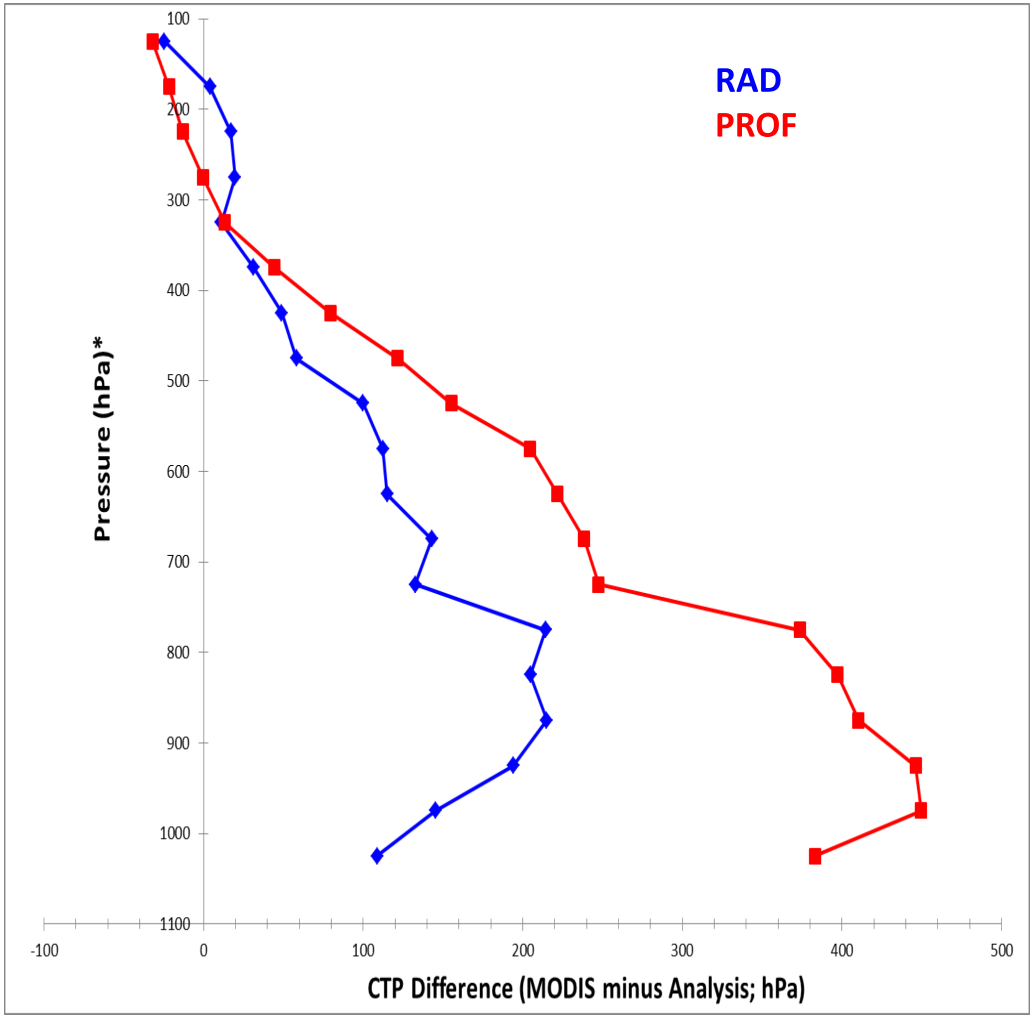
Comparison to MODIS CTP

Assimilated AIRS radiances where CTP was closer to MODIS CTP (listed as tropical (<30^{o}N)/midlatitude (>30^{o}N*)/total)*

		High (< 300 hPa*)	Middle (300-700 hPa*)	Low (> 700 hPa*)
11/22 00Z	PROF	***58/26/84***	**42**/106/148	149/141/290
	RAD	24/10/34	25/***158/183***	***337/702/1039***
11/27 00Z	PROF	***54/72/126***	***46***/81/127	123/187/310
	RAD	32/34/66	22/***133/155***	***287/543/830***
11/29 00Z	PROF	25/0/25	***29***/0/***29***	72/0/72
	RAD	25/0/25	9/0/9	***245***/0/***245***
12/02 00Z	PROF	***43***/0/***43***	***13***/0/***13***	47/0/47
	RAD	35/0/35	5/0/5	***163***/0/***163***
12/09 00Z	PROF	***75***/34/***109***	***48***/112/160	93/94/187
	RAD	23/***73***/96	19/***162/181***	***441/343/784***

**as defined by MODIS*

Comparison to MODIS CTP

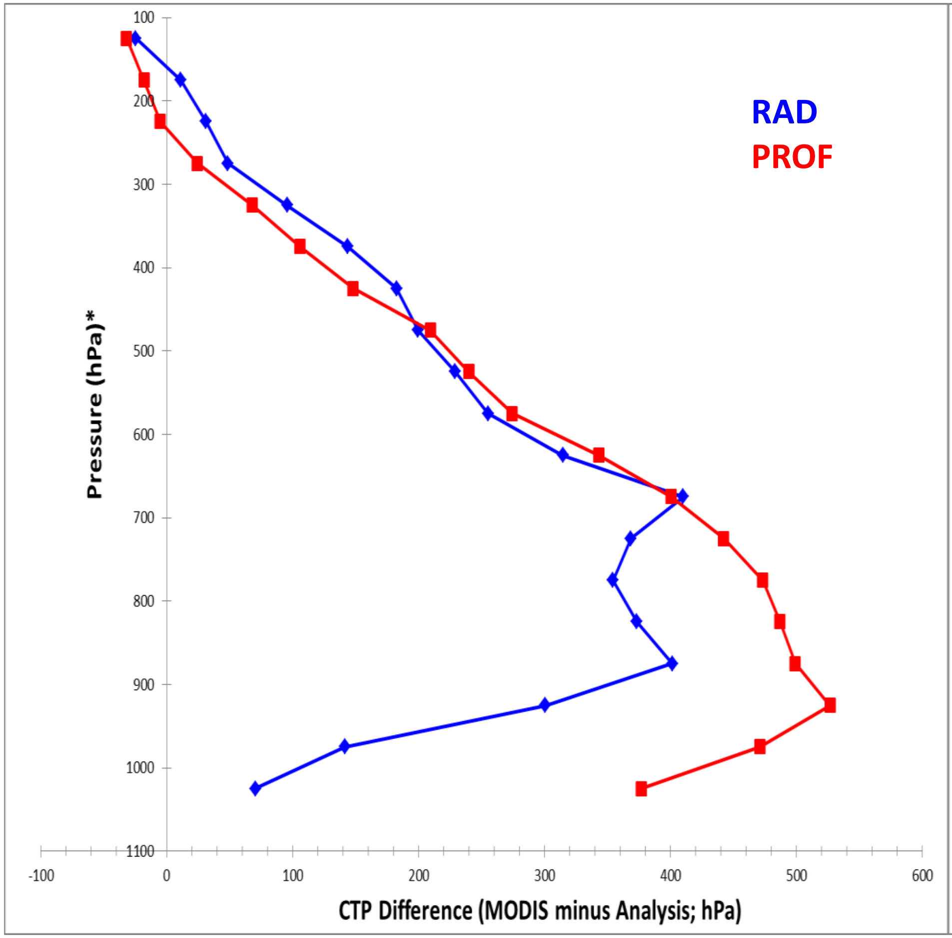


*as defined by MODIS

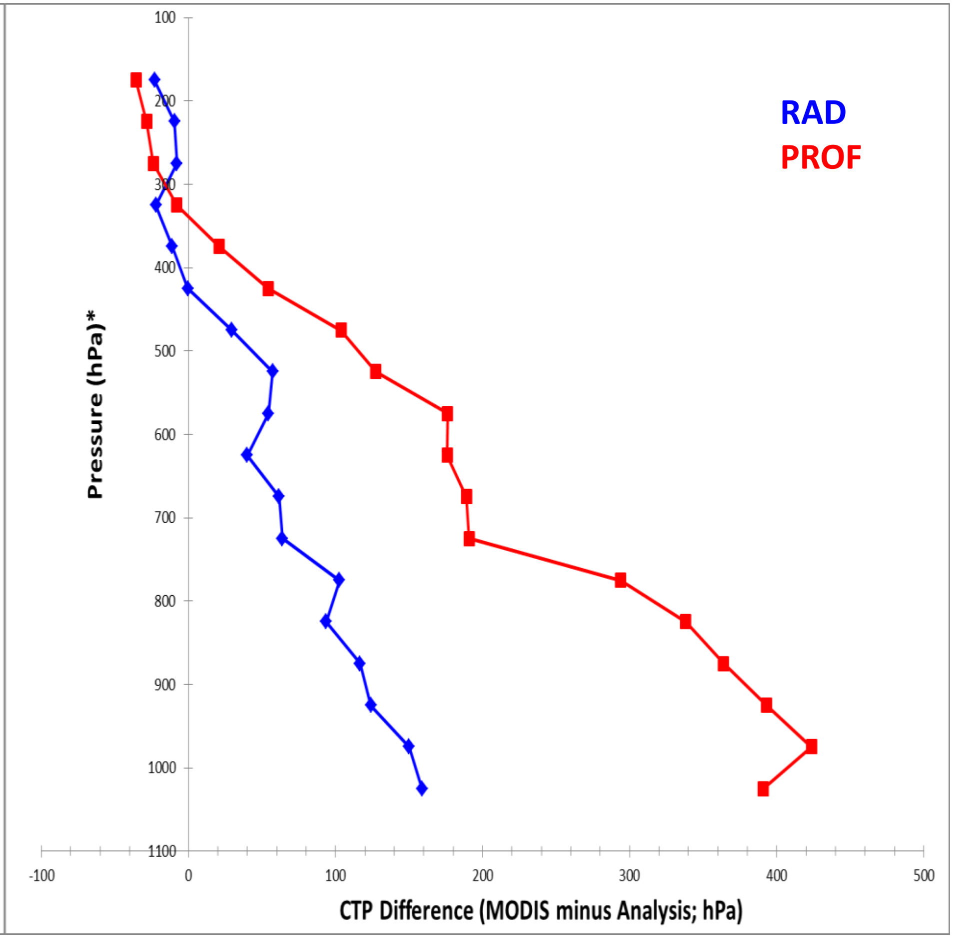
- Using 5 days from previous chart, compare level-by-level cloud detection for "00Z analysis"
- Magnitude is preserved, so positive values indicate analysis CTP is higher in the atmosphere than MODIS (less cloud contamination)
- CTP difference is smaller nearly across the board for the RAD (i.e. CNTL) experiment
- Only highest cloud tops (>150 hPa) exhibit a signal indicating that the GSI-defined CTP is below the MODIS CTP

Comparison to MODIS CTP

“Tropical” points (<30ºN)



“Midlatitude” points (<30ºN)



*as defined by MODIS

Summary/Future Work

- **Summary**
  - Made GSI code modifications to test "swapping" AIRS L2 CTP with CTP derived directly from the radiances within the GSI QC modules
  - Results indicate that <u>GSI does a good job on the whole of determining cloud-free radiances</u>
  - AIRS L2 CTP appears to generally place the cloud higher in the atmosphere than the QC check in GSI, which is likely due to larger footprint of the L2 product
- **Future Work**
  - Investigate use of single FOV retrievals from AIRS to see if CTP in the L2 product is improved there
  - Perform a similar CTP swapping using MODIS; from the results, it is apparent that MODIS CTPs will be lower in the atmosphere than those derived by GSI, which should lead to additional assimilated radiances
  - Apply this new method of defining CTP within GSI for entire case study period and re-process analyses and forecasts to provide a more robust set of statistics

Acknowledgments

- Work is supported by Tsengdar Lee of the NASA Science Mission Directorate through the JCSDA and SPoRT
- EMC staff (Geoff DiMego, Justin Cooke, Michael Lueken, et al.) for helping with our understanding of the cycling, configuration of our system that mimics the operational NAM, and making NAM PREPBUFR observations available to the research community at our request
- Jim Jung and JIBB IT staff for allowing us to run our simulations and store our large analysis and forecast files on these NASA supercomputing resources

Brad.Zavodsky@nasa.gov

256-961-7914